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Terminology for nanoscale measurement and instrumentation

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Summary of pages

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Foreword

Publishing information

This Publicly Available Specification (PAS) has been commissioned by the UK Department for Innovation, Universities and Skills (DIUS) and developed through the British Standards Institution. It came into effect on 31 December 2007.

Acknowledgement is given to the following organizations that were involved in the development of this terminology:

- Keithley Instruments Ltd;
- Malvern Instruments;
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In addition, acknowledgement is given to the contributions of those that commented, including BSI Technical Committee NTI/1, *Nanotechnologies*, the working groups of ISO Technical Committee ISO/TC 229, *Nanotechnologies*, and other organizations and experts.

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This PAS is not to be regarded as a British Standard. It will be withdrawn upon publication of its content in, or as, a British Standard.

The PAS process enables a specification to be rapidly developed in order to fulfil an immediate need in industry. A PAS may be considered for further development as a British Standard, or constitute part of the UK input into the development of a European or International Standard.

Relationship with other publications

This PAS is issued as part of a suite of nanotechnology terminology PASs:

- PAS 71, *Vocabulary – Nanoparticles*;
- PAS 131, *Terminology for medical, health and personal care applications of nanotechnologies*;
- PAS 132, *Terminology for the bio-nano interface*;
- PAS 133, *Terminology for nanoscale measurement and instrumentation*;
- PAS 134, *Terminology for carbon nanostructures*;
- PAS 135, *Terminology for nanofabrication*;
- PAS 136, *Terminology for nanomaterials*.

PAS 131 to PAS 136 include terms the definitions for which differ to those given in PAS 71:2005, which was published in June 2005. These differences are the result of further reflection and debate and reflect consensus within the PAS steering groups. Until PAS 71:2005 can be revised to incorporate these changes, it is intended that the terms in PAS 131 to PAS 136 take precedence over PAS 71:2005.

This suite of PAS acknowledges the standards development work being conducted by BSI Technical Committee NTI/1, *Nanotechnologies*, ISO TC/229, *Nanotechnologies*, IEC/TC 113, *Nanotechnology standardization for electrical and electronic products and systems*, and CEN/TC 352, *Nanotechnologies*. Attempts have been made to align the definitions in these PASs with the definitions being developed by these committees, particularly the draft ISO/TS 27687, *Terminology and definitions for nanoparticles*. However, as the work of these committees is at a development stage, complete alignment has not been possible in every instance.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a Publicly Available Specification cannot confer immunity from legal obligations.

Introduction

Many authorities predict that applications of nanotechnologies will ultimately pervade virtually every aspect of life and will enable dramatic advances to be realized in most areas of communication, health, manufacturing, materials and knowledge-based technologies. Even if this is only partially true, there is an obvious need to provide industry and research with suitable tools to assist the development, application and communication of the technologies. One essential tool in this armoury will be the harmonization of the terminology and definitions used in order to promote their common understanding and consistent usage.

This terminology includes terms that are either specific to the sector covered by the title or are used with a specific meaning in the field of nanotechnology. It is one of a series of terminology PASs covering many different aspects of nanotechnologies.

This terminology attempts not to include terms that are used in a manner consistent with a definition given in the *Oxford English Dictionary* [1] and terms that already have well established meanings and to which the addition of the prefix "nano" changes only the scale to which they apply but does not otherwise change their meaning.

The multidisciplinary nature of nanotechnologies can lead to confusion as to the precise meaning of some terms because of differences in usage between disciplines. Users are advised that, in order to support the standardization of terminology, this PAS provides single definitions wherever possible.

1 Scope

This Publicly Available Specification (PAS) lists terms and definitions used in measurement and/or instrumentation for characterization at the nanoscale and characterization of nanoscale properties by mean of average measurement.

This is applicable to but not limited to terms used in the measurement of chemical, functional and structural properties at the nanoscale.

It is intended for use by technologists, regulators, non-governmental organizations (NGOs), consumer organizations, members of the public and others with an interest in the application or use of nanotechnologies in the subject area.

2 General terms

2.1 microelectromechanical systems (MEMS)
systems with dimensions in the microscale that can respond to an electric (mechanical) stimulus and generate or produce a mechanical (electric) response

*NOTE **MEMS** may be used in **nanometrology** as they might be sensitive to **nanoscale** properties.*

2.2 nanomaterial
material having one or more external dimensions in the **nanoscale** or which is **nanostructured**

NOTE ***Nanomaterials*** *can exhibit properties that differ from those of the same material without* ***nanoscale*** *features.*

2.3 nanometrology
science of measurement of **nanoscale** properties

NOTE ***Nanoscale*** *properties can be measured with probes larger than 100 nm.*

2.4 nanoscale
size range from approximately 1 nm to 100 nm

NOTE 1 Properties that are not extrapolations from larger size will typically, but not exclusively, be exhibited in this size range.

NOTE 2 The lower limit in this definition (approximately 1 nm) has no physical significance but is introduced to avoid single and small groups of atoms from being designated as nano-objects or elements of nanostructures, which might be implied by the absence of a lower limit.

[ISO/TS 27687 [1]]

2.5 nanostructured
possessing a structure comprising contiguous elements with one or more dimension in the **nanoscale** but excluding any primary atomic or molecular structure

NOTE 1 An example of a primary atomic or molecular structure is the arrangement of atoms in a crystalline solid.

NOTE 2 The use of the term contiguous implies that a sphere, of approximately 100 nm diameter, inscribed in a ***nanostructured*** *material will intersect more than one element of the structure.*

3 Nanoscale measurement methods

3.1 Scanning probe methods

3.1.1 atomic force microscopy (AFM)
technique for imaging surfaces by mechanically scanning their contours using a microfabricated probe, in which the deflection of a sharp tip sensing the surface forces, mounted on a soft cantilever, is monitored as the tip is moved across the surface

NOTE Part of the family of microscopies referred to as ***Scanning Probe Microscopy (SPM)****.*

[PAS 71: 2005, definition **10.2**]

3.1.2 contact mode
atomic force microscope mode in which the probe or the sample height is adjusted to keep a constant repulsive force between the probe and the sample

[derived from BS ISO 18115:2001, *Surface chemical analysis – Vocabulary*]

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[1] In preparation.

3.1.3 electrostatic force microscopy (EFM)

AFM mode in which a conductive probe is used to map both topography and electrostatic force between the tip and the sample surface

[derived from BS ISO 18115:2001, *Surface chemical analysis – Vocabulary*]

3.1.4 force-distance curve

pairs of force and distance values resulting from a mode of operation of an **AFM** in which the probe is set at a fixed (x,y) position and the force measured as the probe tip is moved towards or away from the surface

[derived from BS ISO 18115:2001, *Surface chemical analysis – Vocabulary*]

3.1.5 intermittent mode

AFM mode where the probe is operated with a sinusoidal z-displacement modulation such that the probe tip makes contact with the sample for a fraction of the sinusoidal cycle

[derived from BS ISO 18115:2001, *Surface chemical analysis – Vocabulary*]

3.1.6 lateral force microscopy (LFM)

AFM mode measuring the torsional deformation of the cantilever

NOTE The lateral deformation usually depends on the friction between the tip and the surface.

3.1.7 magnetic force microscopy (MFM)

AFM mode measuring the force acting between the magnetic field of the sample and the magnetic dipoles of a cantilever coated with ferromagnetic materials

3.1.8 magnetic resonance force microscopy (MRFM)

scanning probe method which combines the three-dimensional imaging capabilities of magnetic imaging with the high sensitivity and resolution of **atomic force microscopy** by mechanically detecting magnetic resonance signals between a permanent magnet and the spin magnetization of the atoms

3.1.9 nanoprobe

probe used to facilitate measurement at the **nanoscale**

3.1.10 non-contact mode

atomic force microscope mode in which the probe oscillates above the surface and experiences an attractive force during this oscillation

[derived from BS ISO 18115:2001, *Surface chemical analysis – Vocabulary*]

3.1.11 scanning capacitance microscopy (SCM)

AFM mode where an AC bias is applied to a conducting probe in contact with a semiconductor sample generating capacitance variations in the sample which can be detected using a GHz resonant capacitance sensor

NOTE ***SCM*** *measures the change in electrostatic capacitance between the surface and the probe.*

3.1.12 scanning electrochemical microscopy (SECM)

AFM mode in which a conductive probe is used in an electrolyte solution to measure both topography and electrochemical current

[derived from BS ISO 18115:2001, *Surface chemical analysis – Vocabulary*]

3.1.13 scanning Kelvin probe microscopy (SKPM)

AFM non-contact mode which measures the relative potential between the surface and a conductive probe by determining the probe bias for a null alternating current

[derived from BS ISO 18115:2001, *Surface chemical analysis – Vocabulary*]

3.1.14 scanning probe microscopy (SPM)

method in which a probe is scanned over the surface of a sample, usually coupled to a feedback loop. A generic term for all devices using physical interaction between a probe tip and a sample surface for sub-micrometer imaging

NOTE 1 Amongst this family those mentioned in note 2 can be used for nanofabrication, for example, the physical probe can be used to move or place atoms on a surface, change the chemistry of a surface, or remove material from a surface in a controlled manner leaving a textured surface.

NOTE 2 Established types of ***scanning probe microscopy*** *that can be used for nanofabrication include:*

- ***AFM (Atomic Force Microscopy);***
- ***MFM (Magnetic Force Microscopy);***
- ***SNOM (Scanning Near-field Optical Microscopy (or NSOM Near Field Scanning Optical Microscopy));***
- ***SECM (Scanning Electrochemical Microscopy);***
- ***STM (Scanning Tunneling Microscopy).***

3.1.15 scanning tunneling microscopy (STM)

technique for revealing the apparent electron-density-related atomic structure of surfaces, using a needle-like probe near the object under observation; a tunnelling current, which is measured, is generated by altering the potential at the tip of the probe; a 3D representation of the sample surface is generated by rastering the tip over the surface of the object and mapping the distance for constant current level at various points

NOTE ***STMs*** *have also been used to produce changes in the molecular composition of substances.*

[PAS 71:2005, definition **10.28**]

3.2 Ion beam analysis methods

3.2.1 Auger electron spectroscopy (AES)

method in which an electron spectrometer is used to measure the energy distribution of Auger electrons emitted from a surface

[BS ISO 18115, definition **3.5**]

3.2.2 elastic recoil detection

method in which measurement of the elastic scattering of ions is used to analyse for light elements in a solid

NOTE For carbon materials, the method is often used to determine the hydrogen content, for example, in a-C:H.

3.2.3 focused ion beam (FIB)

beam of ions (usually gallium) focused through a set of electrostatic lenses to create a small spot on a substrate

NOTE 1 The beam removes material from the substrate through physical sputtering. The beam spot can be scanned across the surface to create a pattern. Nanometer scale resolution can be obtained in this process.

*NOTE 2 Also know as **FIB** milling.*

NOTE 3 The generated secondary electrons (or ions) can be collected to form an image of the surface of the sample.

*NOTE 4 **FIB** is particularly used for site-specific analysis, deposition and ablation of materials.*

3.2.4 ion beam analysis (IBA)

method to elucidate composition and structure of the outermost atomic layers of a solid material, in which principally mono-energetic, singly charged probe ions, scattered from the surface are detected and recorded as a function of their energy or angle of scattering, or both

[BS ISO 18115, definition **4.8**]

3.2.5 Rutherford back scattering (RBS)

method in which the scattering of high energy ions is used to determine compositional and structural information about a solid

NOTE The technique can be used, for example, to determine the variation of sp^3 *fraction and the density of a carbon film.*

3.2.6 secondary-ion mass spectrometry (SIMS)

method in which a mass spectrometer is used to measure the mass-to-charge quotient and abundance of secondary ions emitted from a sample as a result of bombardment by energetic ions

[BS ISO 18115, definition **4.9**]

3.3 Electron beam methods

3.3.1 electron energy dispersion

method where inelastic interaction of an electron beam with atoms in a sample results in an energy distribution spectrum from which compositional and chemical bonding information can be derived

[derived from PAS 71, *Vocabulary – Nanoparticles*]

3.3.2 electron energy loss spectroscopy (EELS)

method in which the energy distribution spectrum of electrons inelastically scattered as they pass through a material is used to determine compositional and structural information about the material

NOTE For carbon materials, it is a well established method for probing the existence of sp^2 *and* sp^3 *hybridized atoms.*

3.3.3 energy dispersive x-ray spectroscopy (EDX)

electron-excited x-ray spectrometry with a focused electron probe and an electron interaction volume with sub-micrometer dimensions

*NOTE Allows spatially-resolved elemental analysis in **TEM** and **SEM**.*

[derived from BS ISO 23833:2006, *Microbeam analysis – Electron probe microanalysis (EPMA) – Vocabulary*]

3.3.4 photoemission electron microscopy (PEEM)

method that involves imaging the distribution of electrons emitted from a surface when it is illuminated with linearly or circularly polarized x-rays

NOTE Has particular applications in magnetic domain imaging; allows the user to derive all three components of magnetization.

[PAS 71:2005, definition **10.20**]

3.3.5 scanning electron microscopy (SEM)

method for producing magnified images of a specimen by scanning its surface with an electron beam and capturing the scattered electrons

*NOTE 1 **SEM** typically has a spatial resolution of 1 to 10 nm.*

NOTE 2 The method can be used to obtain size, shape, structure and, in some cases, compositional information.

NOTE 3 Some methods use additional detectors, such as an energy dispersive detector, that allow the composition of the sample to be determined with spatial resolutions below 1 m, channelling detectors that allow crystal orientations or strain to be measured, or backscatter detectors that provide atomic contrast.

[derived from PAS 71, *Vocabulary – Nanoparticles*]

3.3.6 selective area electron diffraction (SAED)

diffraction of electrons from an area of the sample selected by an aperture

[PAS 71:2005, definition **10.24**]

3.3.7 transmission electron microscopy (TEM)

method for producing magnified images or diffraction patterns by passing an electron beam through a specimen

*NOTE 1 **TEM** typically requires samples less than 100 to 200 nm thick if internal details are required. Thicker samples may be viewed with higher energies.*

*NOTE 2 **TEM** can be used to image lattice planes and individual row of atoms with resolutions better than 0.2 nm.*

NOTE 3 Some methods use additional detectors, such as an energy dispersive detector or electron energy loss spectrometer, that allow the composition of the sample to be determined with spatial resolutions below 10 nm.

[derived from PAS 71, Vocabulary – Nanoparticles]

3.4 Optical methods and related terms

3.4.1 anti-Stokes scattering

scattering of light by a material where the scattered photon has higher energy than the incident photon

*NOTE 1 This gives rise to an "**anti-Stokes**" line on the higher energy or shorter wavelength side of the incident spectrum.*

*NOTE 2 This term is used in **Raman spectroscopy**.*

3.4.2 confocal scanning microscopy

optical microscopy using a **Nipkow disc** or a laser to produce point-probing raster scanning, yielding images with associated high resolution maps of the surface height

NOTE 1 A small aperture at the secondary focus of the objective lens narrows the depth of focus and obstructs most of the light reflected from out-of-focus objects.

NOTE 2 Microscopy which is able to create an image of the focal point by concentrating light on a specimen using a confocal laser; the method can also measure surface shape by recording height information, which matches the focal point of each scan's line image.

[SEMI D29, derived from *Test Method for Heat Resistance in Flat Panel Display (FPD) Color Filters* [5]]

3.4.3 fourier transform infrared spectroscopy (FTIR)

spectroscopic technique measuring the infrared absorption by a sample

NOTE Used to probe bonding types and structures, e.g., double, triple carbon-carbon bonds, bonds with other elements such as hydrogen, nitrogen, oxygen, present in a carbon material.

3.4.4 near field scanning optical microscopy (NSOM)

method for imaging surfaces in transmission or reflection by mechanically scanning an optical probe much smaller than the wavelength of light over the surface whilst monitoring the transmitted or reflected light

*NOTE 1 Also referred to as scanning **near field optical microscopy (SNOM)**.*

*NOTE 2 Part of the family of microscopes referred to as **SPM, see 3.1.14**.*

3.4.5 Nipkow disc

mechanically spinning disk of any suitable material with a series of equally distanced circular holes of equal diameter drilled in it

3.4.6 photoconductivity

increase in conductivity of a material when illuminated with light

NOTE Gives information on transport and recombination processes for carbon materials.

3.4.7 photoluminescence (PL)

emission of light from a material under optical excitation

NOTE Gives information on the recombination process of electrons and holes, and for carbon materials, it is attributed to the recombination of electron-hole pairs confined in π-rich entities surrounded by a sp^3 matrix.

3.4.8 radial breathing mode (RBM)

strongest low frequency Raman mode for carbon nanotubes

NOTE It is commonly used to determine the diameter of carbon nanotubes.

3.4.9 Raman D-peak

peak in the Raman spectrum of carbon containing materials at about 1 350 cm^{-1} for optical wavelength excitation

NOTE Directly linked to the breathing mode of aromatic carbon rings and is used as indication of "disorder".

3.4.10 Raman effect

scattering of light with a change in frequency characteristic of the scattering substance, representing a change in the vibrational, rotational, or electronic energy of the substance that can be used to give information on its chemical bonding or mechanical stress state

[PAS 71:2005, definition **10.22**]

NOTE Also known as Raman scattering.

3.4.11 Raman G-peak

peak in the Raman spectrum of carbon containing materials at about 1 590 cm^{-1} for optical wavelength excitation

*NOTE Directly linked to sp^2 bonded carbon and is used as an indication of ordering. Many researchers use the I(D)/I(G) ratio of the intensities of the D and G peaks to assess the amount of disorder in carbon films. [Chem. Phys., 2007, **9**, 1276–1290; DOI: 10.1039/b613962k]*[2]*.*

3.4.12 Raman spectroscopy

analysis of the intensity of Raman scattering of monochromatic light as a function of frequency of the scattered light; the information obtained is useful for determining molecular structure

3.4.13 Stokes scattering

scattering of light by a material where the material absorbs energy and the scattered photon has a lower energy

NOTE 1 This gives rise to a "Stokes" line on the lower energy or longer wavelength side of the incident spectrum.

NOTE 2 This term is used in ***Raman spectroscopy****.*

3.5 x-ray and neutron based measurement techniques

3.5.1 near edge x-ray absorption fine structure (NEXAFS)

method that uses measurement of the energies of photons and electrons emitted from matter following irradiation with x-ray photons, which themselves have energies close to the absorption edge of the material, to derive structural information about the irradiated material

NOTE The method can provide valuable information about bonding in molecular structures.

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[2] See http://www.rsc.org/publishing/journals/CP/article.asp?doi=b613962k

3.5.2 small angle neutron scattering (SANS)

technique for measuring the scattering of neutrons at small angles with respect to the incident beam

NOTE May be used to determine the spatial distribution of adsorbed species on a particle.

[PAS 71:2005, definition **10.30**]

3.5.3 small angle x-ray scattering (SAXS)

method in which analysis of the scattering of x-rays at angles close to the transmitted beam is used to determine structural information about materials

NOTE This method can be used to obtain data on ultrananocrystalline diamond nucleation and growth behind the detonation wavefront.

3.5.4 synchrotron radiation small angle x-ray scattering (SRSAXS)

<as **3.5.7**> where synchrotron radiation is used as the source of x-rays

NOTE 1 Synchrotron radiation produces beams with much higher intensity than conventional x-ray sources, allowing much shorter exposure times to be used.

NOTE 2 This method can be used to elucidate aspects of ultrananocrystalline diamond formation kinetics.

3.5.5 total reflection x-ray fluorescence spectroscopy (TXRF)

method in which an x-ray spectrometer is used to measure the energy distribution of fluorescence x-rays emitted from a surface irradiated by primary x-rays under the condition of total reflection

[BS ISO 18115:2001, definition **4.12**]

3.5.6 x-ray auger electron spectroscopy (XAES)

method in which an electron spectrometer is used to measure the energy distribution of Auger electrons emitted from a surface after irradiation with x-rays

NOTE 1 This method is extensively used to determine the bond angles and nearest neighbour atom distance in carbon films. ***NEXAFS XAES*** *data has been used to determine carbon hybridization, and for the detection of diamond-like bonding in a-C films.*

NOTE 2 This method has been used to measure carbon hybridization at the surface of carbon materials such as diamond, a-C and DLC.

3.5.7 x-ray diffraction line broadening (XRDLB)

method for measuring the size and strain of individual crystals under about 0.1 nm, where the Debye rings (x-ray lines) generated by the procedure are broadened

NOTE Strain in the material may also cause x-ray line broadening.

[PAS 71:2005, definition **10.34**]

3.5.8 x-ray photoelectron spectroscopy (XPS)

method in which an electron spectrometer is used to measure the energy distribution of photoelectrons and Auger electrons emitted from a surface irradiated by x-ray photons

[BS ISO 18115, definition **4.14**]

3.6 Nanoparticle measurement methods and related terms

3.6.1 aerodynamic diameter
diameter of a unity-density sphere having the same gravitational settling velocity as the particle in question

[*Aerosol Measurement: Principles, Techniques and Applications* [6]]

3.6.2 BET analysis
characterization method based on the model developed by Brunauer, Emmet and Teller that allows the surface area of powders to be determined by gas adsorption

NOTE Typically nitrogen or carbon dioxide is used but gases such as krypton or argon may be used for low surface area materials because of their greater sensitivity (mass gain per unit area).

[PAS 71:2005, definition **10.4**]

3.6.3 condensation particle counter (CPC)
most widely used type of instrument for detecting and counting nanoparticle aerosols, which operates by condensing vapour onto sampled ultrafine particles to grow them to a size range that can be detected by a standard optical counter

[PAS 71:2005, definition **10.6**]

3.6.4 diffusion diameter
diameter of a unity-density sphere having the same rate of diffusion as the particle in question

[*Aerosol Measurement: Principles, Techniques and Applications* [6]]

3.6.5 differential mobility analysis (DMA)
method of establishing the size distribution of aerosols, based on the principle of the mobility of a charged particle in an electric field

[PAS 71:2005, definition **10.7**]

3.6.6 dynamic light scattering (DLS)
method of determining the **hydrodynamic diameter** by measuring the diffusion speed of particles or molecules undergoing Brownian motion, using a coherent laser beam illuminating the material dispersed at a suitable concentration in a liquid. The decay of the autocorrelation function of the measured intensity of the scattered light is interpreted as an average particle size and polydispersity index can be obtained using the cumulants method, and information about size distribution can be obtained using a range of algorithms

NOTE ***DLS*** *is also known as photo-correlation spectroscopy (PCS).*

[derived from ISO 13321-8:1996, *Methods for determination of particle size distribution – Photon correlation spectroscopy*]

3.6.7 epiphaniometer
instrument used to measure the Fuchs surface area of aerosols directly: the aerosol is passed through a charging chamber where lead isotopes created from a decaying actinium source are attached to the particle surfaces; the particles are transported through a capillary to a collecting filter; the amount of radioactivity measured is proportional to the particle surface area

[PAS 71:2005, definition **10.10**]

3.6.8 equivalent diameter
diameter of a sphere having the same rate of diffusion as the particle in question

[*Aerosol Measurement: Principles, Techniques and Applications* [6]]

3.6.9 field flow fractionation (FFF)
method of separating particles in a fluid flowing in a channel by applying a field perpendicular to the flow, e.g. a transverse flow or thermal field

[PAS 71:2005, definition **10.11**]

3.6.10 hydrodynamic diameter
effective diameter of a particle in a liquid environment

NOTE 1 The ***hydrodynamic diameter*** *measured by* ***dynamic light scattering*** *is referred to as the Z-average mean.*

NOTE 2 See ***equivalent diameter (3.6.8)****.*

[PAS 71:2005, definition **9.5**]

3.6.11 mean size
average of all sizes, that is, the sum of all sizes divided by the number of particles

[*Aerosol Measurement: Principles, Techniques and Applications* [6]]

3.6.12 median size
size with an equal number of particles above and below this value

[*Aerosol Measurement: Principles, Techniques and Applications* [6]]

3.6.13 mobility diameter
diameter of a spherical particle with the same dynamic mobility as the particle in question

[*Aerosol Measurement: Principles, Techniques and Applications* [6]]

3.6.14 mode size
peak size of a distribution of particle sizes

3.6.15 scanning mobility particle sizing (SMPS)
method for detecting and counting nanoparticles, which gives both size and number information, and is capable of measuring aerosol size distribution from 3 to 800 nm; operates by charging particles and separating them based on their mobility when passing between electrodes

NOTE The size distribution is expressed in terms of particle ***mobility diameter****.*

3.7 Electro-magnetic techniques

3.7.1 Hall effect

development of a transverse electric field in a solid material when it carries an electric current and is placed in a magnetic field perpendicular to the current

NOTE With this measurement, it is possible to determine the type, concentration, and mobility of carriers in the materials.

3.7.2 Hall probe

semiconductor-based probe which uses the **Hall effect** to allow the strength of a magnetic field to be measured

3.7.3 Lorentz microscopy

type of **transmission electron microscopy** using the interaction of the electron beam with the magnetic induction of a **nanoscale** structure to create an image of the magnetic structure of a sample

3.7.4 superconducting quantum interference device (SQUID)

devices formed of superconducting loops containing Josephson junctions used to measure magnetic fields

3.8 Mechanical techniques

3.8.1 nano-indentation

method where indentor is pressed into surface to a maximum depth of 100 nm with continuous monitoring of the indentation force and resultant indentor penetration enabling the determination of local mechanical properties

3.8.2 nano-scratch

method where transverse sample movement during a **nano-indentation** experiment produces scratches which can be used to determine the adhesion strength of thin films and coatings

NOTE Repetitive scratches allow study of ***nanoscale*** *wear.*

3.8.3 surface acoustic wave

acoustic or vibrational wave travelling on the surface of a sample

3.9 Thermal techniques

3.9.1 thermogravimetric analysis (TGA)

method in which the mass of a sample of material is measured as a function of temperature.

NOTE Useful in determining the thermal stability or composition of materials.

4 Abbreviations

AES	Auger Electron Spectroscopy
AFM	Atomic Force Microscope
CPC	Condensation Particle Counter
DLS	Dynamic Light Scattering
DMA	Differential Mobility Analysis
EDX	Energy Dispersive X-ray Spectroscopy
EELS	Electron Energy Loss Spectroscopy
EFM	Electrical Force Microscopy
FFF	Field Flow Fractionation
FIB	Focused Ion Beam
IBA	Ion Beam Analysis
LFM	Lateral Force Microscopy
MFM	Magnetic Force Microscopy
MRFM	Magnetic Resonance Force Microscopy
NSOM	Near-Field Scanning Optical Microscopy
PCS	Photon Correlation Spectroscopy
PEEM	Photoemission Electron Microscopy
SAED	Selective Area Electron Diffraction
SANS	Small Angle Neutron Scattering
SCM	Scanning Capacitance Microscopy
SECM	Scanning Electrochemical Microscopy
SEM	Scanning Electron Microscopy
SIMS	Secondary-Ion Mass Spectrometry
SKPM	Scanning Kelvin Probe Microscopy
SMPS	Scanning Mobility Particle Sizing
SPM	Scanning Probe Microscopy
SQUID	Superconducting Quantum Interference Device
SRSAXS	Synchrotron Radiation Small Angle X-ray Scattering
STM	Scanning Tunnelling Microscope
TGA	Thermogravimetric Analysis
TEM	Transmission Electron Microscopy
TXRF	Total Reflection X-ray Fluorescence Spectroscopy
XPS	X-ray Photoelectron Spectroscopy
XAES	X-ray Auger Electron Spectroscopy
XRDLB	X-ray Diffraction Line Broadening

Bibliography

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

PAS 71:2005, *Vocabulary – Nanoparticles*

BS ISO 18115:2001, *Surface chemical analysis – Vocabulary*

BS ISO 23833:2006, *Microbeam analysis – Electron probe microanalysis (EPMA) – Vocabulary*

ISO/TS 27687, *Terminology and definitions for nanoparticles* [3)]

ISO 13321-8:1996, Methods for determination of particle size distribution – Photon correlation spectroscopy

Other publications

[1] *Shorter Oxford English Dictionary*, 6th edition. Oxford: Oxford University Press, 2007.

[2] GOODSON, L., C.L. GLADYS, D.E. WORST, Numbering and Naming of Fullerenes by Chemical Abstracts Service, *J. Chem. Inf. Comp. Sci.* 1995.

[3] *Occupational Ultrafine Aerosol Exposure Characterization and Assessment*, Particle Size Selective Sampling and Analysis (Workplace Air Quality) Draft Technical Report, ISO/TC146/SC2/WG1ISO 18115.

[4] Keithley Instruments, Inc. *Handbook of nanotechnology*. 2007.

[5] SEMI D29-*1101*, *(Reapproved 0707)*, *Test Method for Heat Resistance in Flat Panel Display (FPD) Color Filters.*

[6] Baron, Paul., Willeke, Klause, *Aerosol Measurement: Principles, Techniques and Applications.* John Wiley and Sons Ltd.

[7] IUPAC *Compendium of Chemical Terminology*, 2nd edition, Royal Society of Chemistry, 1997.

Further reading

PAS 130, *Guidance on the labelling of manufactured nanoparticles and products containing manufactured nanoparticles*

PD 6699-1, *Nanotechnologies – Part 1: Good practice guide for specifying manufactured nanomaterials*

PD 6699-2, *Nanotechnologies – Part 2: Guide to safe handling and disposal of manufactured nanomaterials*

[3)] In preparation.

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